CLAIMS

What is claimed is:

1. A method for processing data packets received from a network, the method comprising the steps of:

(A) storing each received data packet in a buffer;

(B) dynamically updating a first threshold value based on (i) variation in packet transit time over the network and (ii) data packets arriving out-of-sequence;

(C) performing a comparison based on a waiting time of a data packet and the first threshold value; and

(D) transmitting the data packet from the buffer for further processing based on the comparison of step (C).

2. The invention of claim 1, wherein:

the data packets are organized in the buffer into one or more frames, each frame comprising one or more data packets;

the first threshold value is updated every time a new data packet is stored in the buffer;

each frame is assigned a frame-release threshold based on the first threshold value;

step (C) comprises the step of comparing the waiting time of an oldest data packet in a current frame to the frame-release threshold; and

step (D) comprises the step of sequentially transmitting all of the data packets in the current frame from the buffer for the further processing based on the comparison of step (C).

3. The invention of claim 2, wherein step (D) further comprises the steps of starting a new frame and assigning the frame-release threshold for the new frame based on a current value of the first threshold value.

4. The invention of claim 1, wherein, for each data packet, step (B) comprises the steps of:

(B1) generating an estimated current packet waiting time;

(B2) generating a variation measure;

(B3) generating an out-of-sequence error; and

(B4) updating the first threshold value based on the estimated current packet waiting time, the variation measure, and the out-of-sequence error.

5. The invention of claim 4, wherein, for step (B):

the estimated current packet waiting time corresponds to an integral of variation in packet transit time over the network

the variation measure corresponds to jitter in the packet transit time; and

the out-of-sequence error corresponds to additional waiting time due to the presence of the out-of-sequence packets.

6. The invention of claim 5, wherein, for step (B4), the first threshold value is limited to be no less than a specified lower limit and no greater than a specified upper limit.

7. The invention of claim 4, wherein, for step (B), the first threshold value $T(i)$ is set to:

T_{min}, *if* $b(i) + \mu v(i) + e(i) \leq T_{min}$;

$b(i) + \mu v(i) + e(i)$, *if* $T_{min} < b(i) + \mu v(i) + e(i) < T_{max}$; or

T_{max}, *if* $b(i) + \mu v(i) + e(i) \geq T_{max}$, wherein:

$b(i)$ is the estimated current packet waiting time;

$v(i)$ is the variation measure;

$e(i)$ is the out-of-sequence error;

μ is a first weighting coefficient;

T_{min} is a lower limit; and

T_{max} is an upper limit.

8. The invention of claim 7, wherein for step (B) the out-of-sequence error $e(i)$ is set to:

$e(i) = c(i)$, *if* $j(i) \geq j_{max}(i-1)+1$, or

$e(i) = c(i) + (d(i) - d^*(i-1))$, *if* $j(i) \leq j_{max}(i-1)$, wherein:

$c(i)$ is a recursive value;

$j(i)$ is the transmission sequence number corresponding to an *i-th* packet;

$j_{max}(i-1)$ is the largest transmission sequence number corresponding to the data packets in the jitter buffer prior to arrival of the *i-th* packet;

$d(i)$ is packet departure time for the *i-th* packet; and

$d^*(i-1)$ is packet departure time for the packet whose transmission sequence number is $j_{max}(i-1)$.

9. The invention of claim 8, wherein for step (B) the recursive value $c(i)$ is set to:

$c(i) = c(i-1)$, *if* $j(i) = j_{max}(i-1)+1$,

$c(i) = c(i-1) + (d(i) - d^*(i-1))$, *if* $j(i) > j_{max}(i-1)+1$, or

$c(i) = c(i-1) - s(i)$, *if* $j(i) \leq j_{max}(i-1)$, wherein:

$c(i-1)$ is a current value of the recursive value;

$s(i)$ is the length of the *i-th* packet.

10. The invention of claim 7, wherein for step (B) the estimated current packet waiting time $b(i)$ and the variation measure $v(i)$ are set to:

$b(i) = \alpha b(i-1) + (1-\alpha)\Delta t(i)$; and

$v(i) = \alpha\, v(i-1) + (1-\alpha)\,|b(i) - \Delta t(i)|$, wherein:

$b(i-1)$ is a current value of the estimated current packet waiting time;

$v(i-1)$ is a current value of the variation measure;

$\Delta t(i)$ is delay-expected inter-arrival time corresponding to an *i-th* packet; and

α is a second weighting coefficient.

11. The invention of claim 7, wherein for step (B) the estimated current packet waiting time $b(i)$ is set to:

$b(i) = \alpha b(i-1) + (1-\alpha)\Delta t(i)$, *if* $\Delta t(i) \leq b(i-1)$, or

$b(i) = \beta b(i-1) + (1-\beta)\Delta t(i)$, *if* $\Delta t(i) > b(i-1)$; and

the variation measure $v(i)$ is set to:

$v(i) = \alpha\, v(i-1) + (1-\alpha)\,|b(i) - \Delta t(i)|$, wherein:

$b(i-1)$ is a current value of the estimated current packet waiting time;

$v(i-1)$ is a current value of the variation measure;

$\Delta t(i)$ is delay-expected inter-arrival time corresponding to an *i-th* packet;

α is a second weighting coefficient; and

β is a third weighting coefficient.

12. The invention of claim 1, wherein for step (A) the data packets comprise audio data packets.

13. The invention of claim 12, wherein the audio data packets comprise voice over Internet Protocol (VoIP) data packets.

14. The invention of claim 1, wherein the method is implemented in a processor of an integrated circuit.

15. A buffer for processing data packets transmitted over a network, comprising:

a memory configured to store each received data packet; and

a controller configured to (A) dynamically update a first threshold value based on (i) variation in packet transit time over the network and (ii) data packets arriving out-of-sequence; (B) perform a comparison based on a waiting time of a data packet and the first threshold value; and (C) transmit the data packet from the buffer for further processing based on the comparison.

16. The invention of claim 15, wherein:

the data packets are organized in the buffer into one or more frames, each frame comprising one or more data packets;

the first threshold value is updated every time a new data packet is stored in the buffer;

each frame is assigned a frame-release threshold based on the first threshold value; and

the buffer is further configured to compare the waiting time of an oldest data packet in a current frame to the frame-release threshold and sequentially transmit all of the data packets in the current frame from the buffer for the further processing based on the comparison.

17. The invention of claim 16, wherein the buffer is further configured to start a new frame and assign the frame-release threshold for the new frame based on a current value of the first threshold value.

18. The invention of claim 15, wherein, for each data packet, the buffer is configured to generate an estimated current packet waiting time, a variation measure, and an out-of-sequence error; and to update the first threshold value based on the estimated current packet waiting time, the variation measure, and the out-of-sequence error.

19. The invention of claim 18, wherein:

the estimated current packet waiting time corresponds to an integral of variation in packet transit time over the network

the variation measure corresponds to jitter in the packet transit time; and

the out-of-sequence error corresponds to additional waiting time due to the presence of the out-of-sequence packets.

20. The invention of claim 19, wherein the first threshold value is limited to be no less than a specified lower limit and no greater than a specified upper limit.

21. The invention of claim 18, wherein the buffer is further configured to set the first threshold value $T(i)$ to:

T_{min}, *if* $b(i) + \mu v(i) + e(i) \leq T_{min}$;

$b(i) + \mu v(i) + e(i)$, *if* $T_{min} < b(i) + \mu v(i) + e(i) < T_{max}$; or

T_{max}, *if* $b(i) + \mu v(i) + e(i) \geq T_{max}$, wherein:

$b(i)$ is the estimated current packet waiting time;

$v(i)$ is the variation measure;

$e(i)$ is the out-of-sequence error;

μ is a first weighting coefficient;

T_{min} is a lower limit; and

T_{max} is an upper limit.

22. The invention of claim 21, wherein the buffer is further configured to set the out-of-sequence error *e(i)* to:

$e(i) = c(i), if\ j(i) \geq j_{max}(i\text{-}1)+1$, or

$e(i) = c(i) + (d(i) - d^{*}(i\text{-}1)), if\ j(i) \leq j_{max}(i\text{-}1)$, wherein:

c(i) is a recursive value;

j(i) is the transmission sequence number corresponding to an *i-th* packet;

$j_{max}(i\text{-}1)$ is the largest transmission sequence number corresponding to the data packets in the jitter buffer prior to arrival of the *i-th* packet;

d(i) is packet departure time for the *i-th* packet; and

$d^{*}(i\text{-}1)$ is packet departure time for the packet whose transmission sequence number is $j_{max}(i\text{-}1)$.

23. The invention of claim 22, wherein the buffer is further configured to set the recursive value *c(i)* to:

$c(i) = c(i\text{-}1), if\ j(i) = j_{max}(i\text{-}1)+1$,

$c(i) = c(i\text{-}1) + (d(i) - d^{*}(i\text{-}1)), if\ j(i) > j_{max}(i\text{-}1)+1$, or

$c(i) = c(i\text{-}1) - s(i), if\ j(i) \leq j_{max}(i\text{-}1)$, wherein:

c(i-1) is a current value of the recursive value;

s(i) is the length of the *i-th* packet.

24. The invention of claim 21, wherein the buffer is further configured to set the estimated current packet waiting time *b(i)* and the variation measure *v(i)* to:

$b(i) = \alpha b(i\text{-}1) + (1\text{-}\alpha)\Delta t(i)$; and

$v(i) = \alpha\, v(i\text{-}1) + (1\text{-}\alpha)\,|\, b(i) - \Delta t(i)\,|$, wherein:

b(i-1) is a current value of the estimated current packet waiting time;

v(i-1) is a current value of the variation measure;

$\Delta t(i)$ is delay-expected inter-arrival time corresponding to an *i-th* packet; and

α is a second weighting coefficient.

25. The invention of claim 21, wherein the buffer is further configured to set the estimated current packet waiting time *b(i)* to:

$b(i) = \alpha b(i\text{-}1) + (1\text{-}\alpha)\Delta t(i), if\ \Delta t(i) \leq b(i\text{-}1)$, or

$b(i) = \beta b(i\text{-}1) + (1\text{-}\beta)\Delta t(i), if\ \Delta t(i) > b(i\text{-}1)$; and

the variation measure *v(i)* is set to:

$v(i) = \alpha\, v(i\text{-}1) + (1\text{-}\alpha)\,|\,b(i) - \Delta t(i)\,|$, wherein:

$b(i\text{-}1)$ is a current value of the estimated current packet waiting time;

$v(i\text{-}1)$ is a current value of the variation measure;

$\Delta t(i)$ is delay-expected inter-arrival time corresponding to an *i-th* packet;

α is a second weighting coefficient; and

β is a third weighting coefficient.

26. The invention of claim 15, wherein the buffer is implemented in an integrated circuit.